UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

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Distr.
LIMITED

E/ECA/NRD/MRU/CW1/83/6
13 June 1983

Original: ENGLISH

ECONOMIC COMMISSION FOR AFRICA

Regional Workshop on the Role of Coal
in Accelerated African Economic Growth

Addis Ababa (Ethiopia), 11-15 July 1983

COAL DEVELOPMENT AND UTILIZATION IN OTHER AREAS OUTSIDE AFRICA

(Prepared by the secretariat of the
Economic Commission for Europe)[1/]

1/ At the request of the secretariat of the Economic Commission for Africa

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INTRODUCTION

1. In the last three decades rising supplies of oil on the world market were the basis of economic growth, but increased demand and production gradually has brought about a depletion of its reserves and, in spite of the present over-supply, the availability of this fuel will be reduced in the long run.

2. Sufficient energy supplies are an indispensable prerequisite of economic development and improved living conditions, particularly in the economically less developed countries. All primary forms of energy and energy conservation will have to be developed but, owing to its abundant reserves and wide range of application, coal will play a principal role in bridging the expected gap in world energy supplies.

3. An increased use of coal requires large investments in mining, preparation, transportation, storage, power stations and other facilities, but not greater than for other fuels, such as oil, gas and nuclear energy. The realization of investment projects for the whole process, from coal to utilization site, needs long lead times. Appropriate measures should be taken to avoid or, at least, limit to acceptable levels the environmental impact of coal mining and use.

A. WORLD COAL RESERVES - SITUATION IN AFRICA

4. Reserves of fossil fuels in the world - technically and economically recoverable - were assessed by the World Energy Conference 1980 at 917.6 billion tons of coal equivalent (btce), of which 667.5 btce (72.8%) coal, 131.9 btce (14.4%) oil and 90.2 btce (10.7%) natural gas. Hence, reserves of coal are three times higher than oil and gas combined.

5. The distribution of world coal reserves among particular regions is shown in Table 1. As can be seen, African reserves constitute 42.7 btce or 4.8 per cent only of global reserves. Experts are of the opinion that by intensifying prospection and exploration, Africa could extend its coal reserves considerably.

6. Known coal reserves in Africa are shown in Table 2. Some coal was also discovered in Ethiopia and Madagascar.

B. WORLD COAL PROSPECTS - ROLE OF AFRICA

7. The secretariat of the UN Economic Commission for Europe recently prepared a study entitled "World coal trade up to the year 2000" (COAL/WP.1/R.83/Add.1) for the Coal Committee and its Working Party on

Coal Trade. It includes a survey of coal prospects by country, region and the world as a whole for 1980 and 2000, embracing in particular demand, production and trade; the reference year being 1980. Most of the basic data contained therein were provided by Governments and the World Bank or derived from the UN Yearbook of World Energy Statistics, 1980.

8. A summary of world coal prospects, in million tons of coal equivalent (mtce) is given in Table 3, and the ensuing percentage share of each region in global coal demand, production, imports and exports in Table 4. Africa's contribution is presented in Table 5. These tables indicate that compared with 1980 Africa's coal demand, production and export would be about three times higher in 2000. Its share in world demand would increase from 2.8 per cent in 1980 to 4.6 per cent in 2000; production from 3.7 per cent to 5.9 per cent; and exports from 10 per cent to 17.8 per cent. Coal imports would merely play an insignificant role.

9. It should, however, be emphasized that one country solely - South Africa - would account for most of the developments on that continent. The coal prospects for all other African countries combined are shown in Table 6. Between 1980 and 2000, the demand of these countries would increase considerably - almost four times; production six times; imports three times; and exports twenty-six times. Unfortunately, the volume of coal would continue to be low in all-African terms (except for imports) and very small on a world scale. There is already a huge potential of coal reserves. The amount - 7.4 btce - could sustain the production of 5.7 mtce achieved in 1980 over a period of more than a thousand years. Consequently, in terms of known coal reserves and in view of the likelihood of further reserves being found, production could be intensified appreciably and contribute to meeting the needs of overall economic development in many African countries.

C. NEW METHODS AND TECHNOLOGICAL ADVANCES IN COAL EXPLOITATION

(a) Underground mining

10. Already in the nineteenth century, coal mining had developed on a large scale in Europe and North America. Coal was originally mined at seam outcrops on the surface. The seam was followed as far as possible and, later, simple shafts were sunk nearby and the coal extracted around them. As mechanical equipment for ventilation, water drainage and coal handling improved, roadways were progressively cut into the coal further from the shaft, generally leaving pillars of coal or timber props and bars to support

the strata. More effective means of drainage, allowed deeper seams to be reached.

11. With the accumulation of mining experience it became possible to win coal more systematically. As a result, the room-and-pillar method was introduced and applied, especially in working gassy seams at greater depth. The gotten coal was hand-filled onto small wagons, the transport most frequently used, and gradually replaced by conveyors. Roof control was carried out by caving. As the room-and-pillar system with caving, used in a number of variants, destroyed the neighbouring seams lying above the extraction panels in multi-seam coal beds, it gave rise to great losses. Moreover, the high proneness of coal to spontaneous combustion necessitated the abandoning of large areas of coal as safety pillars which, together with pillars between rooms, entailed further losses amounting to 60 per cent and more of available reserves. The increasing depth of mining generated mounting rock pressures in seams and strata, made it more and more difficult to maintain in a proper state the indispensable mine workings, in particular roadways. As a result, the room-and-pillar method is now used only marginally in Europe. However, in the United States it is still the predominant method due to relatively shallow deposits and very efficient and completely mechanized coal getting by means of continuous miners.

12. Alarmingly high losses and increasing friction ties in coal getting contributed largely to the formation of a new exploitation method - longwall mining, applicable in all seam thicknesses and in most conditions of coal occurrences. With this method, longwall faces need much less road-driving than room-and-pillar mining. Coal pillars are either not needed at all, or limited to a minimum, thus the recovery factor can be very high - up to 90 per cent. The continuous advance of longwall faces facilitates the control of rock stresses around the workings, which is of considerable importance for work safety. Most important - the longwall method makes it possible to mechanize all operations connected with the coal-winning process.

13. Longwall mining was introduced in Europe on a wider scale in the 1920s and 1930s. Between 1930 and 1970, it replaced almost completely the room-and-pillar method, except where it could not be made use of.

14. An outstanding advantage of the longwall method is its susceptibility to mechanization and automation of particular operations. This is of vital importance because face operations are the hardest, most time-consuming and dangerous. So the technical progress introduced in this field has a decisive influence on the improvement of economic results of mining.

Large-scale mechanization has taken place in the flat thick seams only. In the 1950s, mostly scraper conveyors were used for coal transport at the face. They replaced the shaker or belt conveyor. The common method of coal getting was blasting, enhanced frequently by cutting machines. Adjustment of the machines to move on armoured face conveyors permitted their use for loading the major part of the coal blasted. The roof was supported even by timber and, later, by metal props - friction or hydraulic - and bars. Further progress in coal winning was made by cutter-loaders. However, a break-through was the introduction of plough (or rather coal) and shearer-loaders which virtually eliminated the need for blasting along the face, except for stable holes. With these machines, a distinct rise in output and improved productivity in the longwall face was obtained.

15. As the technique of roof support using single props and bars has lagged considerably behind mechanized cutting, loading and transportation of coal, further progress in the extraction method was hampered severely. Since the late 1950s, the situation has improved remarkably with the introduction of self-advancing powered supports; at the beginning, the frame and chock type and, later, the shield type which proved to be most suitable to prevailing conditions of mining. A modern longwall face is basically equipped with powered supports, a shearer-loader or plough as well as an armoured face conveyor, all integrated into a fully mechanized system. The standard length of such faces is 150-250 m. A wide range of integrated systems of mechanized longwall equipment is now available to meet the variegated natural conditions encountered in coal mining. In the leading European coal industries, the average output of such a face is 800-1,400 t/d, although record results of 8,000 t/d and more have been achieved. Consequently, in a colliery a few longwall faces and development headings only are needed to achieve the production objectives. As a result, the transportation system is simplified and the organization more efficient.

16. When roof control by caving is not possible and there are objects to be protected against undermining, the disposable part behind the longwall face is filled with fine stone or sand by means of pneumatic or hydraulic stowing. However, this techniques entails additional costs due to a more complex system of work and the need for specific skills and equipment.

17. Exploitation of more than 4-m thick seams is generally carried out by multi-lift method, the height of the lift (slice of the seam) to be extracted being 2-3.5 m, depending on local conditions. If hydraulic stowing is used, the bottom lift is the first to be extracted and then successively the upper lifts; in the case of roof caving, the order of extraction is reversed.

In this case, it is necessary to lay a so-called artificial floor usually made of wire mesh to create a roof for the next lift. For this purpose, a coal layer - at least 0.5 m thick - is left between the lifts. One is also made of a mixed method by which, after mining the lower lift with stowing, the roof lift is extracted with caving. A lift is mined by conventional longwalling which may simultaneously be applied to several lifts, a stable pillar distance is maintained between subsequent faces.

18. Since the 1960s, great efforts have been made in the field of face automation. The reason has not been the removal of men from the faces but rather measures and control techniques to improve face performance, ease manual work and cope with natural disturbances. While mining operations can be automated substantially, with the role of man essentially supervisory, in general, no attempt is made to cope with all the unforeseen and difficult situations that may arise. The flexibility and ingenuity of the miner are still required to handle abnormal or infrequent occurrences, without the need for uneconomic or technically difficult solutions.

19. It was recognized that the proper guidance of the coal face was a major requirement of automation. It has been proven that a lack of roof guidance can be the source of many delays associated with face equipment as well as the cause of losses in progress and output. A simple vertical steering control system was developed for a fixed drum shearer-loader to be used in thicker seams. However, it was a much more difficult task to provide vertical steering for ranging drum shearers, but research and development work to find a satisfactory solution are being carried out. There are three aspects which affect horizontal guidance: straightness of the face between the gates; angle of face to the gates; and advance of face. The monitoring of these aspects, based on mobile surveying methods using the shearer, and static methods which measure the face advance at many points, is also only at the research and development stage.

20. Systems of remotely and automatically operated roof supports are well advanced; a number of which have been in use on a commercial scale in several countries. Their objectives are to improve both safety and production. The removal of operators from the vicinity of the supports reduces the risk of injuries due to roof falls or plant movement as well as damage to health fro dust and noise. Automatically-sequenced operation of supports reduces operating time, provides consistent setting loads and improves face advance by controlling the push-over distance. It is recognized that a complete control of mechanized roof supports can be achieved only by integrating the system and the monitoring system for face guidance and alignment.

21. A number of mines are equipped with a system of performance measurements, aiming to provide the colliery management with facts concerning the coal faces. It monitors the state of the major face equipment and identifies delays. The surface operator must assign a cause to each delay. Data are presented in a form allowing the identification and improvement of problems. The face information system is intended to include other operational details as well as health monitoring, with displays of information at other parts of the mine relevant to production. It is expected that the data obtained will lead the way to overcoming current constraints, indicate those coal face operations which mostly need automatic control, and provide a valuable basis on which future coal face systems could be designed.

22. The further spread of technology to control coal face operations constitutes a major part of research and development programmes in the leading American and European coal industries. It is assumed that, later in this decade, the application of automation techniques will have a major impact on methods and production results.

23. It must be borne in mind that installation of integrated face mechanization is very expensive - costing several million dollars, or more. Its application is justified only when a high daily coal output, say 1,000 t/d or more, can be achieved over a long period. Obviously, the running of such installations can be carried out by experienced and skilled personnel only. Therefore, companies having no relevant mining experience or human and material potential are advised rather to introduce less sophisticated coal-winning technology with partial mechanization only, and later to decide on the application of more complex methods.

24. As the further development of conventional coal-mining methods involved certain technical and environmental constraints, it induced some countries to experiment with unconventional technologies. One of the most promising appears to be underground coal gasification, and later liquefaction. They could be used to extract fuel from coal deposits, including those unsuitable for mining by conventional methods. Consequently, underground gasification could contribute to enlarging recoverable coal reserves.

(b) Opencast mining

25. In many parts of the world, where thick and shallow seams occur, opencast mining provides much of total coal output. These are often low-rank deposits - lignites or brown coal - and can profitably be exploited. Some opencast mines are enormous, producing more than 10 million tons of coal annually, but there are also small-size operations yielding special quality coals, such as anthracite or prime coking coal. Opencast technology is well advanced. However, the size of the deposit, together with the scale and amount of equipment, are generally the limiting factors of production.

26. Opencast mining is based mainly on the use of draglines, with buckets scooping up tens of tons at a time. Large mechanical shovels, bulldozers and bucket wheel excavators may also be used. The top soil is first removed and placed to one side, exposing the coal seams which are then progressively extracted. The intervening dirt bands may be removed separately. In some cases, coal seams are several dozen meters thick. Depths of overburden of over 200 m are feasible and total depths of 500 m or more can be worked. The depth of mining and the ratio of overburden to seam thickness are the most important factors in deciding the optimum size of the surface areas needed to be available. The most favourable deposits for large-scale opencast mining are often located in remote, underdeveloped areas. In these locations, new large operations would frequently require the provision of infrastructure.

27. Opencast mining makes it necessary to restore the land after coal extraction. Great progress has been made in the restoration of farm land, by careful preservation and replacement of the top soil. In all areas, the restoration of contours and diversion or pollution of streams may, nonetheless, constitute very contentious issues. Thus, environmental considerations linked to opencast mining may have serious economic aspects.

D. COAL PREPARATION, TRANSPORT AND STORAGE

28. There are rigid requirements for coal quality parameters, such as low contents of ash, sulphur and humidity; uniform grain size; high calorific value; specific-coking properties; etc. As the run-of-mine output is a mixture of coal and dirt, it needs upgrading before being sent to the customer. The raw coal is first sized and the coarse coal separated from dirt either by jigging in water or by dense medium separation. The fine coal below 0.5 mm is cleaned by froth flotation. The cleaning process reduces the ash and, to a lesser degree, the sulphur content. The washing processes use water and this is largely removed from the products by centrifuges or vacuum filters. For a few special markets, or if the clean coal has to be transported very far, the coal is further dewatered by thermal drying.

29. Coal production is closely connected with the necessity of having a transport infrastructure on the surface. There are some favourable cases where coal can be moved to the point of consumption by conveyor belts. They are confined to distances of several kilometers. In some instances, for longer-distance transport, such conveyors may also be used where there would be difficulties with other systems. For most inland movements, however, rail transport is preferred to carry coal by unit trains commuting between mines and major consumers. A usable river network provides the opportunity for very

cheap transport of coal by barges. For some time now, a number of coal-slurry pipelines have been in operation and there is growing enthusiasm for this method. In ocean coal shipment, vessels of different sizes are employed. A number of countries already have, or are developing, port facilities for ships up to 150,000 dead-weight tons.

30. The suitability of coal to be stored in a pile is a useful feature which allows energy supply options to be increased. However, coal while being stored, may deteriorate in quality (especially coking coal) and become prone to spontaneous combustion. To avoid these problems, techniques have been worked out in recent decades. They consist in building stockpiles over a substantial area by adding thin layers evenly, with consolidation of each level. These methods facilitate homogenization, particularly important with coking coals. Very good mixing can be guaranteed by layering coal horizontally and recovering it by cutting vertical slices with a bucket-wheel excavator.

E. COAL UTILIZATION

31. Coal is a very heterogeneous source of energy, characterized by a complex chemical composition and differentiated petrographic structure. It consists mainly of carbon, hydrogen, oxygen and small quantities of nitrogen and sulphur. It also contains inorganic impurities. Coal is made of high-molecular compounds evolved through condensation reactions from a blend of vegetable origin. It even has a greater processing potential than crude oil and natural gas. As coal is a solid and complex substance, high scientific expertise and technological skill are required to fully understand its potential.

32. At the beginning, industrial revolution was founded on the use of coal in two important fields: the raising of steam for motive power and the smelting of metals, especially iron. They are equally important nowadays; most of the steam is used in central generating stations for the production of electricity. Apart from that, coal is also used by various industries in combustion units for the production of steam, both for process heat and power generation; this is likely to become the most rapidly growing industrial market in the medium term.

33. To generate electricity, coal is dried, ground and burned in a boiler to raise steam that drives a turbine. In most modern power stations, it is burned in the form of pulverized fuel. Powdered coal is injected with air into a hot furnace, where it burns in a flame, heat being recovered in steam-generating water tubes lining the furnace walls. Much progress has been made in improving the efficiency of electricity generation: in the 1950s, the efficiency of power stations was commonly around 20 per cent, now the best modern base-load stations achieve an efficiency of up to 40 per cent, which

has been made possible by increases in the temperature of the steam. However, this is now close to the maximum possible with conventional construction materials. Much work is being carried out to reduce the particulate and gas emissions in order to meet increasingly strict environmental regulations. With current technology, a reduction of 99.8 per cent in particulate emissions can be achieved using either electrostatic precipitators or bag houses. A more difficult problem concerns the reduction of sulphur oxide emissions. Sulphur occurs in coal both in organic combination and inorganic form, mainly as pyrite. The latter can usually be removed from coal by cleaning techniques. The remainder is released as sulphur dioxide during combustion and requires removal, by law in many countries, from the flue gases. Wet scrubbers in which the sulphur is absorbed, usually by lime, are used commercially. Regenerative scrubbing systems, being at an advanced stage of development, are a more effective solution. They result in the recovery of sulphur in its elemental and, thus, useful form. Another noxious problem is caused by nitrogen oxide emissions. The formation of this gas can be reduced by an appropriate control of combustion conditions to lower peak temperatures and reduce excess air. New processes are at an advanced stage of development for the chemical removal of nitrogen oxides from gaseous emissions.

34. In the residential and commercial sectors, and in industry (e.g. cement; aluminium, bricks, ceramics and glass; food, beverage and tobacco; engineering; pulp and paper; textiles), almost all energy is used for heat production, now mainly provided by oil and gas. In these sectors, there is a large potential of coal as a substitute for other fuels. Great effort is being made to develop technologies increasing the efficiency and flexibility of coal combustion, extending the range of coals that may be used in a furnace, and helping to decrease environmental problems associated with coal combustion. The most interesting are fluidized-bed combustion, production of stabilized coal-in-oil suspensions and their use in furnaces designed for oil, and magneto-hydrodynamic (MHD) technology.

35. Fluidized-bed combustion overcomes the limitations of grates and pulverized fuel furnaces. This system - having a number of versions suitable for different purposes - is considered very promising and will probably become the principal combustion method. Fluidized-bed combustion is called so because the coal particles being burned are in a state of fluidity by the upward flowing stream of combustion air. These conditions are favourable for a good heat transfer and high intensity of heat release, although at moderate, controlled temperatures. The process allows the absorption of sulphur oxides when crushed limestone is used in the bed. The low combustion temperature reduces substantially the formation of nitrogen oxides. It is also possible to use grades of coal

containing very high quantities of ash, even coal preparation waste can be burned. Due to a more efficient heat transfer to the water pipes running through the fluidized bed, the production units can be smaller than conventional boilers with the same output. The simpler versions of fluidized combustion are likely to make early and substantial penetration into the market for small- and medium-size industrial boilers. Pressurized fluidized-bed combustion units, currently under development, have the potential advantages of being even more compact and providing more efficient sulphur and nitrogen oxide reduction. Moreover, the pressurized flue gas can be put through a combined-cycle turbine for improvement of the efficiency of electricity generation. However, commercialization of this technology will probably require several years more than fluidized-bed combustion at atmospheric pressure because many problems have yet to be solved.

36. In some countries, there is increased interest in the prospects of using pulverized coal dispersed in fuel oil. These coal-oil mixtures (COM) may use coal as a fuel in existing oil-fired installations to the extent of 20-50 per cent. In planning to switch oil-burning equipment to COM firing, the following factors should be taken into consideration: long-term stability of the mixture, formation of slag from ash, derating of boiler performance, and the installation of additional gas-cleaning equipment and coal-oil mixing facilities. However, for new boilers, the most efficient approach is to design for direct coal combustion.

37. The magneto-hydrodynamic (MHD) technology aims at producing electricity directly from very hot combustion gases without the use of steam or gas turbines. The gas is generated with a temperature of more than 2000°K, containing a seed material (e.g. potassium) that is readily ionized to render the gas electrically conductive (plasma), passing it with high velocity through a transverse magnetic field. An MHD generator combined with a steam-cycle system could achieve efficiencies of 45-55 per cent compared with 40 per cent in conventional power stations. However, many difficulties, especially related to the development of high-temperature resistant materials, have yet to be overcome before the technology could be applied on a commercial scale.

38. In the carbonization process, coal is heated by contact with air in special coke ovens. The volatile matter is driven off, yielding valuable gaseous and liquid products which may be recovered. In most cases, however, the coke which remains is the main product. It can react at high temperatures to reduce metal oxides either directly or, more efficiently, by reacting first with oxygen to form carbon monoxide which then acts as a reductant. One of the great advantages of coke in smelting processes is that it can be made into a

strong and stable form which can withstand thermal and mechanical forces and also chemical reactions at low temperatures. Its reactions can then be centralized in suitable hot areas in process equipment, such as blast furnaces. To this end, high grade coal, i.e. metallurgical coal, must be used which, however, constitutes not more than 20 per cent of global hard coal reserves. Therefore, technologies have been developed to produce coke from lower-grade coals. As an alternative to coke, the so-called "formed coke" may be made from fine coal in a variety of processes and, in the future, increased use of it could be made as a substitute for coke-oven coke.

39. An outstanding advantage of coal is its suitability to conversion into gaseous and liquid fuels which will be produced in increasing amounts in the not too distant future with the progressive exhaustion of supplies of natural gas and crude oil.

40. Current interest in coal gasification aims at a total conversion of coal to gas, with little or no residue or by-products. In principle, all coal gasification processes involve the reaction of coal with steam to form carbon monoxide and hydrogen. Because this reaction is highly endothermic - requiring energy to run the process - some of the coal is reacted simultaneously with oxygen to provide heat. This reaction produces carbon dioxide or, with adequate control of oxygen availability, more carbon monoxide. Thus, the primary fuel gas derived from coal consists mainly of carbon monoxide and hydrogen in varying amounts. In terms of calorific value, three kinds of gas may be produced from coal. If air is used for the carbon-oxygen reaction, a low-calorie gas is obtained (3.8-7.6 MJ/m^3) because it is diluted with the air nitrogen. This gas is uneconomic for transport and must be used on the spot for power generation or industrial application. Since the gas has to be cleaned to remove the sulphur prior to final utilization, the product is an environmentally acceptable gas. If oxygen is used instead of air, a medium-calorie gas is produced (10-16 MJ/m^3). It can be sent by pipeline over reasonable distances and used directly for industrial and domestic purposes. This gas is of special value as feedstock for the chemical industry; as a source of hydrogen, methane and methanol; and as a component in liquid fuel production. High-calorie gas (over 21 MJ/m^3) - mainly methane - is produced in the methanation reaction from a blend of carbon monoxide and hydrogen, that is from medium-calorie gas. If methane alone - i.e. substitute natural gas (SNG) - is to be produced, it is necessary to adjust the carbon monoxide to hydrogen molecular ratio to 1:3 by reacting some of the carbon monoxide with steam to form hydrogen and carbon dioxide, the latter being removed. There are many coal gasification processes under development. The variety reflects the great heterogeneity and variability of coal, complex chemistry of conversion,

engineering problems connected with gasification, and the different qualities of product gas that are required. Research on new technologies is conducted with the input of various gasifying substances (steam, oxygen, air, hydrogen), in a wide range of temperatures (400°-1,700°C) and pressures (1-100 atm). As feedstock, coals and other solid fuels are used with various methods of ash or char disposal. In the processes under development, a tendency can be perceived to elevate the pressures (which increase the throughput) and make the process independent of the coal quality. The most distinguishing feature of particular technologies is the type of the reactor bed in which the gasifying reaction takes place: fixed, fluidized, entrained and molten.

41. Coal liquefaction produces a range of products, from clean liquid fuels for power stations to a synthetic crude oil that can be refined to make a variety of liquid fuels and chemicals. For many uses, such as motor fuel, there are no other satisfactory alternatives to liquid fuels. That is the principal reason for the interest in converting coal into liquids. In addition, the need to increase coal use in electricity generation, while meeting environmental protection requirements, has also enhanced interest in producing clean liquid fuels from coal. There are three general approaches to coal liquefaction: pyrolysis, hydrogenation and gasification followed by conversion of synthesis gas into liquids. In all approaches, hydrogen is needed, either initially as in hydrogenation and/or subsequently as in pyrolysis and hydrogenation to upgrade the products. Thus, all coal liquefaction processes require some gasification of coal or of the carbonaceous residue from pyrolysis or hydrogenation, with steam to produce the required hydrogen. In pyrolysis processes, coal is destructively distilled at high temperatures in the absence of air. A redistribution of the hydrogen occurs in coal to produce liquid and gaseous products as well as a carbonaceous residue. In all pyrolysis processes, the major product is a char that can be used directly as a fuel and as a feedstock for fuel gas, synthesis gas and liquid fuel production. When high-sulphur coals are involved, the char product retains a great amount of sulphur. Liquids derived from coal pyrolysis are complex tars requiring hydrogenation to render them suitable for use as clean fuels. In hydrogenation, the non-catalytic approaches are directed essentially to high-efficiency conversion of coal to a product that is liquid at process temperatures with a minimum hydrogen consumption because hydrogen is the most expensive element of liquefaction. The objective is the removal of sulphur-containing carbonaceous and mineral residues by physical means (mainly filtration or centrifugal separation) to produce a fuel for direct use in utility and industrial boilers or for further upgrading into motor fuels. The objective of the direct catalytic hydrogenation is to produce a liquid product suitable for direct use as a heavy fuel oil or feedstock (syncrude) for

transport fuels. This requires the use of catalysts and higher pressures than non-catalytic hydrogenation. The advantage of liquefaction of synthesis gas is that it can be applied to low-grade and high-ash coals; when transport fuels are required, the shortcoming of this technology is poor selectivity. A further improvement in this situation can be expected through a process in which a catalyst is used that allows quantitative conversion of methanol to gasoline. Because methanol can be selectively produced from synthesis gas using a suitable catalyst, there is renewed hope that a robust catalyst can be developed to permit a selective direct conversion of coal-based synthesis gas to gasoline.

F. CONCLUSIONS

42. Coal is produced in opencast and underground mining. In each case, a great number of technologies have been developed and adapted to diverse mining conditions. In the leading coal industries, mining is completely mechanized and some operations are automated.

43. Coal is now destined primarily for electricity generation and coke-making, but finds increasing application in many industries. The technologies for coal utilization are becoming more and more sophisticated to achieve the widest possible range of products at enhanced conversion efficiencies, and to meet the stringent regulations concerning the protection of the environment.

44. The coal reserves of Africa, although relatively modest in comparison with those of other regions, are sufficiently abundant to give rise to a considerable intensification of production. Efforts which may be undertaken to find new coal occurrences on the continent are likely to be successful.

45. An infrastructure for coal transport and use has to be built corresponding to increasing output capacities.

46. The amount of capital required for modern coal mining and utilization technologies is high and lead times preceding the attainment of full capacities long, but it may be completely justified in cases of indigenous primary energy resources, such as coal. This is particularly true with regard to those African countries which possess recoverable coal deposits but, at the same time, have to import oil, with the result that there is a heavy drain on national reserves of hard currency.

47. Unless there are well-founded reasons for large-scale coal development projects, it seems advisable to construct first of all small and simple coal production and utilization units; they could possibly be followed later by others, larger and more sophisticated. For instance, in mining it would be preferable - wherever possible - to develop opencast mines for which the average capital and operational costs would be lower and lead times shorter, than for underground mines.

48. It is also essential to have a properly skilled work force for the implementation of coal development programmes.

Table 1

WORLD COAL RESERVES[1/]

REGION	btce[*/]	%
Western Europe	90.5	13.2
Eastern Europe	46.4	6.7
USSR	165.5	24.1
China	99.0	14.4
Far East	16.0	2.3
Japan	1.1	0.2
United States	190.9	27.8
Canada	4.4	0.6
Central America	1.5	0.2
South America	3.0	0.4
South Africa	25.3	3.7
Other Africa	7.4	1.1
Australia	36.5	5.3
WORLD TOTAL	687.5	100.0

[*/] Billion tons of coal equivalent.

Table 2

COAL RESERVES IN AFRICA[1/]
(Million tons of coal equivalent)

Rank	Country	Hard coal	Sub-bituminous coal and lignite	Total coal equivalent
1	South Africa	25,290	-	25,290
2	Botswana	3,500	-	3,500
3	Swaziland	1,820	-	1,820
4	Zimbabwe	734	-	734
5	Zaire	600	-	600
6	Mozambique	240	40	280
7	Tanzania	200	-	200
8	Nigeria	-	131.8	131.8
9	Morocco	50	-	50
10	Algeria	42.9	-	42.9
11	Zambia	24	-	24
12	Egypt	13	-	13
13	Malawi	12	-	12
14	Central African Republic	-	1.3	1.3
	AFRICA TOTAL	32,525.9	173.1	32,699

1/ Source: World Energy Conference 1980.

Table 3

WORLD COAL PROSPECTS UP TO THE YEAR 2000[1/]
(in million tons of coal equivalent)

Region	Demand			Production			Import			Export			Net trade (+net import-net export)		
	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
EUROPE	1230.6	1620.3	1783.3	1167.9	1439.3	1617.9	157.6	249.5	330.9	-83.8	-118.5	-165.5	72.8	131.0	165.4
Western Europe	418.2	592.5	725.8	336.4	399.3	438.2	120.8	214.3	298.3	-28.0	-21.1	-10.7	92.8	193.2	287.6
Eastern Europe	812.4	1027.8	1057.5	831.5	1090.0	1179.7	36.8	35.2	32.6	-55.8	-97.4	-154.8	-19.0	-62.2	-122.2
AMERICA	638.8	908.2	1367.6	725.0	1043.0	1620.2	24.3	21.1	21.4	-92.8	-155.9	-274.0	-68.5	-134.8	-252.6
North America	615.9	859.2	1288.6	709.6	986.9	1494.3	16.3	14.7	14.3	-92.8	-148.4	-229.0	-76.5	-127.7	-205.7
Latin America	22.9	49.0	79.0	15.4	56.1	125.9	8.0	6.4	7.1	-	-12.5	-54.0	8.0	-7.1	-46.9
AFRICA	74.9	142.8	222.4	97.8	184.7	304.6	0.9	3.4	2.5	-24.0	-44.3	-84.7	-23.1	-40.9	-82.2
ASIA	671.0	1096.1	1533.5	600.6	936.2	1303.6	73.5	172.9	266.2	-6.6	-33.0	-36.3	74.0	159.9	229.9
OCEANIA	39.0	98.6	145.0	73.3	209.1	306.1	-	-	-	-34.3	-130.5	-161.1	-34.3	120.5	-161.1
WORLD	2660.3	3866.0	5051.8	2664.6	3862.3	5152.4	261.3	445.9	621.0	-241.5	-442.2	-721.6	19.8	3.7	-100.6

1/ ECE secretariat study: World coal trade up to the year 2000 (COAL/WP.1/R.83/Add.1).

Table 4

SHARE OF PARTICULAR REGIONS IN GLOBAL COAL DEMAND, PRODUCTION, IMPORT AND EXPORT 1/
(per cent)

Region	Demand			Production			Import			Export		
	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
EUROPE	46.2	41.9	35.3	42.6	36.6	31.4	60.3	56.0	53.3	34.7	26.8	22.9
Western Europe	15.7	15.3	14.4	12.6	10.4	8.5	46.2	48.3	48.0	11.6	4.8	1.5
Eastern Europe	30.5	26.6	20.9	31.2	26.2	22.9	14.1	7.9	5.3	23.1	22.0	21.4
AMERICA	24.0	23.5	27.1	27.2	27.0	31.4	9.3	4.7	3.4	38.4	35.3	30.0
North America	23.1	22.2	25.5	26.6	25.6	29.0	6.2	3.3	2.3	38.4	32.2	30.5
Latin America	0.9	1.3	1.6	0.6	1.4	2.4	3.1	1.4	1.1	-	3.1	7.5
AFRICA	2.8	3.7	4.1	3.7	4.0	5.8	0.4	0.5	0.4	10.0	10.0	11.5
ASIA	25.5	28.3	30.3	22.5	24.2	25.3	30.0	38.8	42.9	2.7	2.9	3.0
OCEANIA	1.5	2.6	2.9	2.8	5.4	6.0	-	-	-	14.2	25.0	22.3
WORLD	100	100	100	100	100	100	100	100	100	100	100	100

1/ ECE secretariat study: World coal trade up to the year 2000 (COAL/WP.1/R.83/Add.1).

Table 5

COAL PROSPECTS UP TO THE YEAR 2000 - AFRICA[1/]
(in million tons of coal equivalent)

COUNTRY	DEMAND			PRODUCTION			IMPORT			EXPORT			NET TRADE (+ net import-net export)		
	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
geria	0.3	0.4	0.5	-	0.1	0.2	0.3	0.3	0.3	-	-	-	0.3	0.3	0.3
gola	-	2.0	2.0	-	2.0	2.0	-	-	-	-	-	-	-	-	-
tswana	0.4	0.7	1.0	0.4	1.8	13.5	-	-	-	-	-1.1	-12.5	-	-1.1	-12.5
ypt	0.2	2.5	2.7	-	0.7	0.9	0.2	1.8	1.8	-	-	-	0.2	1.8	1.8
dagascar	-	2.0	2.0	-	2.0	2.0	-	-	-	-	-	-	-	-	-
rocco	0.7	1.1	1.5	0.7	1.0	1.3	-	0.1	0.2	-	-	-	-	0.1	0.2
zambique	0.3	1.0	2.0	0.4	3.0	9.0	0.2	-	-	-0.3	-2.0	-7.0	-0.1	-2.0	-7.0
geria	0.2	3.0	3.0	0.2	3.0	3.0	-	-	-	-	-	-	-	-	-
uth Africa	68.9	122.4	200.0	92.1	162.4	264.0	..	-	-	-23.2	-40.0	-64.0	-23.2	-40.0	-64.0
aziland	-	-	-	0.2	0.9	0.9	-	-	-	-0.2	-0.9	-0.9	-0.2	-0.9	-0.9
ire	0.3	0.3	0.3	0.1	0.1	0.1	0.2	0.2	0.2	-	-	-	0.2	0.2	0.2
mbia	0.5	2.5	2.5	0.5	2.5	2.5	-	-	-	-	-	-	-	-	-
mbabwe	3.1	4.9	4.9	3.2	5.2	5.2	-	-	-	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
RICA TOTAL	74.9	142.8	222.4	97.8	184.7	304.6	0.9	2.4	2.5	-24.0	-44.3	-84.7	-23.1	-41.9	-82.2

ECE secretariat study: World coal trade up to the year 2000
(COAL/WP.1/R.83/Add.1).

Table 6

COAL PROSPECTS OF AFRICA (EXCLUDING SOUTH AFRICA)[1/]

	DEMAND			PRODUCTION			IMPORT			EXPORT		
	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Million tons of coal equivalent	6.0	20.4	22.4	5.7	22.3	40.6	0.9	2.4	2.5	-0.8	-4.3	-20.7
Share in all-African volume %	8.0	14.3	10.1	5.8	12.1	13.3	100.0	100.0	100.0	3.3	9.7	24.4
Share in global volume %	0.2	0.5	0.4	0.2	0.6	0.8	0.3	0.5	0.4	0.3	1.0	2.9

1/ Source: World coal trade up to the year 2000 (COAL/WP.1/R.83/Add.1)